Granular Activated Carbon (GAC)

GAC can be used to remove dissolved contaminants from water by adsorption.

Figure 1. Activated Carbon [4]

1.0 Applicable Contaminants

GAC is an EPA BAT for the following contaminants:

- Disinfection Byproducts (DBPs)
- Mercury and Cadmium
- Natural Organic Matter
- Synthetic Organic Chemicals (specifically: benzo(a)pyrene, di(2-ethylhexyl)adipate, di(2-ethylhexyl)phthalate, hexachlorobenzene, dioxin)
- Radionuclides

2.0 Description of Technology

Pretreatment For source water with an unstable amount of bacteria, filtration and disinfection prior to carbon treatment may be required. Filtration prior to GAC may also be required when dealing with high-TSS waters.

Technology Description GAC has an extremely large amount of adsorption surface area, generally around 73 acre/lb (650 m^2/gram) to 112 acre/lb (1000 m^2/gram) [1]. GAC is made of tiny clusters of carbon atoms stacked upon one another, and is produced by heating the carbon source (coal, lignite, wood, nutshells or peat) in the absence of air which produces a high carbon content material [3].

The adsorption isotherm for carbon and the source water will determine the total contaminant removal capacity [2]. The iodine # is also used to represent the small and large pore volumes in a sample of GAC. It is the actual mass of iodine that is absorbed from the carbon sample. GAC is often used for the removal of natural organic mater, as well as disinfection by-products. The physical removal of a contaminant by adsorption on to the carbon surface is done in the mass transfer zone (MTZ). Breakthrough is defined as the point at which the concentration of a contaminant in the effluent adsorption unit exceeds the treatment requirement [1]. This breakthrough time is important to note so that treatment goals are not exceeded, and backwashing rates can be optimized. Backwashing a GAC system follows the same general procedures as a conventional granular gravity filter system. The GAC will typically expand up to 75% to 100% in volume, but may be only as much as 50% [1]. Empty bed contact time (EBCT) is the volume of the empty bed divided by volumetric flow rate of water through the carbon. A typical bed depth can contain up to 50% freeboard, excess capacity beyond the designed capacity, to allow for bed expansion during backwashing. Surface loading rates, or the volume of water that is passing though a given area, typically range from 2 to 6 gpm/ft^2 (5 to 15 m/h) [1].

The American Water Works Association (AWWA) sets standards on the amount of moisture content that GAC contains (no more than 8% by weight). The percent of ash content should also be considered, as a high percentage can cause problems in hard water. Particle size should also be considered, as it impacts the pressure drop across the filter, the backwash rate, the carbon usage rate (CUR), and the overall filtration capabilities. Powdered activated carbon (PAC) is also an option, but is mainly used when carbon filtration is necessary on a seasonal basis.

Biological growth can be desirable within GAC, which results in what is known as biologically active carbon (BAC). BAC can be beneficial by removing assimilable organic carbon (AOC) and other biodegradable compounds. If it is intended to have BAC, the GAC filters are typically preceded by ozonation that breaks down the organic carbon into a more assimable form. This process can enhance the overall contaminant removal of the GAC process. However, the biological growth needs to be controlled with frequent backwashing (once every 5 days). The use of chlorine prior to the beds will not prevent growth, will produce DBPs which take up more GAC adsorption sites, and make the carbon more brittle. Disinfection is recommended after the GAC filters to prevent biological growth in the distribution system, and to achieve the highest removal of AOC within the plant. If biological growth is not controlled and anaerobic conditions develop, odor problems will occur and undesirable organisms will begin to grow. Significant head loss and shorter filter runs can occur with too much biological growth. These two factors will be impacted even with beneficial biological growth and should be accounted for in GAC design [1].

The overall performance of an adsorption treatment process depends on the following factors:

1) Physical properties of the GAC: source of raw carbon, method of activation, pore size distribution, and surface area
2) Chemical and electrical properties of the carbon source or method of activation. The hydrogen and oxygen content in the GAC impacts performance as well.
3) Chemical composition and concentration of contaminants
4) The temperature and pH of the water. Adsorption usually increases as temperature and pH decrease [6].
5) The flowrate and exposure time to the GAC. The lower the contaminant concentration and flowrate tend to increase the life of the GAC [1].

GAC treatment technologies include:

- Pour-through devices for treating small volumes, such as a hand held Brita® filter.
- Faucet-mounted (with or without bypass) for treating water at a single faucet
- In-line filter (with or without bypass) for treating large volumes for several faucets
- High-volume commercial units for treating community water supply systems. Typically they are gravity fed (larger volumes) or pressure driven (smaller volumes) contactors [1]. These high-volume units can be sequenced in parallel or in series. GAC filters can be used alone or can also be combined with media filters.

Careful selection of type of carbon to be used is based on the contaminants in the water and manufacturer's recommendations.

Maintenance Regular reactivation or replacement of carbon media is required. If a GAC plant is large enough regeneration can be done on site, but is typically performed off site. On-site regeneration is typically not effective unless the carbon exhaustion rate is larger than 910 kg/day [1]. Reactivation frequency is dependent on contaminant type, concentration, rate of water usage, and type of carbon used. Careful monitoring and testing to ensure contaminant removal is achieved is necessary around the time of start up and breakthrough. Flushing is required if the carbon filter is not used for several days, and regular backwashing may be required to prevent bacterial growth [1].

Waste Disposal Disposal of spent media is typically the responsibility of the contractor providing the media replacement or reactivation service. Backwash/flush water disposal is a required waste stream if it is included in the design of the filter [1].

Benefits

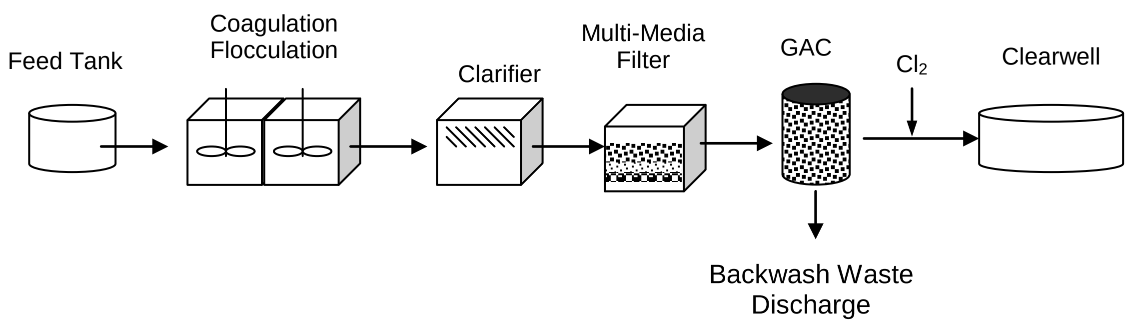
- Well established treatment technique
- Suitable for many organic chemicals, NOM, and trihalomethanes (THMs)
- Suitable for home use
- Able to improves taste and odor, and removes chlorine

Limitations

- Relatively expensive O&M cost for regeneration
- Effectiveness is based on contaminant type, concentration, rate of water usage, and type of carbon used
- Requires careful monitoring when nearing breakthrough times

3.0 Example Treatment Train

The GAC treatment train typically includes raw water pumps, debris screens, gravity filters, GAC units, chlorine disinfection, and clearwell storage.



4.0 Safety and Health Concerns

- Spent carbon may contain high levels of hazardous substances
- Regeneration by-products including toxic gases such as dioxins and furans[1]

5.0 References

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